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High power broadband singlelobe InGaAsP/InP superluminescent diode

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Abstract. Superluminescent diodes (SLDs) operating in 1300–1550 nm wavelength range with high output power (40 mW), wide spectra width (65 nm at FWHM), low modulation depth ($< 1\%$) and singlelobe far-field pattern have been fabricated. The optimum SLD is 10° tilted mesa-stripe construction with back absorbtion section based on broad gain profile InGaAsP/InP separate confinement double heterostructure.

Introduction

Superluminescent diodes (SLD) are the optimum light sources for optical low coherence reflectometry [1] and fiber gyroscopes due to their short coherence length, low intrinsic noise and broad emission spectra. In this connection broadband SLD emitting in 1300–1550 nm wavelength range with high output optical power and effective coupling with singlemode optical fiber is of great interest.

The main problem to obtain high power superluminescent emission is to reach high optical gain within diode without optical feedback. The most effective ways of Fabry–Perot modes suppression are the following: deposition of antireflection coating on diode facets [3], introduction of unpumped absorbing region [4–5], tilted stripe formation [6].

This paper reports on the investigation and fabrication of optimum SLD construction for the achievement of maximum cw output power of singlelobe broadband superluminescent emission with low spectral modulation. SLD was based on mesastripe laser diode construction [7] on the base of InGaAsP/InP separate confinement double heterostructure (SC DH) grown by modified version of LPE technology [8]. 800 Å active layer and 1 μm waveguide thicknesses were chosen in the case of SLD construction. Mesastripe laser structure with 4 μm stripe width provides effective coupling in singlemode optical fiber with 50% coupling coefficient [7]. Laser diodes on the base of such construction have low threshold current, high internal and external quantum efficiency and high output power in single transverse mode operation [7]. Our previous investigations [9, 10] showed that such laser diodes possess anomalously wide lasing and spontaneous emission spectra. An existence of very broad gain profile [10] makes such structure very attractive for the fabrication of SLD with high output power and broad emission spectra.

1 Experimental results and discussion

To achieve superluminescent emission SC DH InGaAsP/InP mesa stripe laser diode construction was modified with the aim of lasing suppression. Influence of each introduced change in the construction on such diode output characteristics as lasing threshold current, output power and efficiency of superluminescent emission, emission spectra width and spectra modulation was examined.

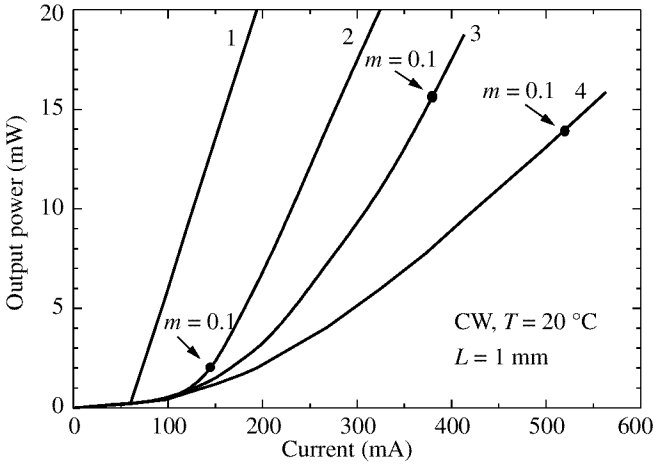

Fig. 1. CW light-current characteristics of SC DH InGaAsP/InP ($\lambda = 1.55\,\mu$m) SLD of mesa construction with tilted stripe angle α: 1—$\alpha = 0°$ (laser diode), 2—$\alpha = 5°$, 3—$\alpha = 10°$, 4—$\alpha = 14°$.

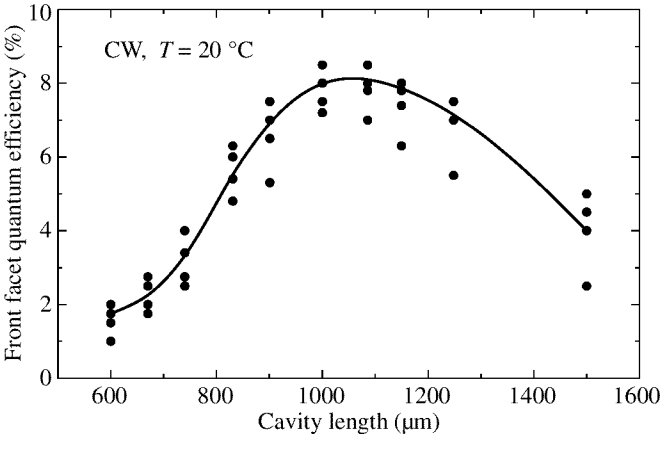

Fig. 2. The dependence of differetial quantum efficiency per facet on cavity length of 10° tilted mesastripe SC DH InGaAsP/InP ($\lambda = 1.55\,\mu$m) SLD.

Investigation of radiation characteristics of SLD with different tilted stripe angle α (from 0° to 14°) and different cavity length L allowed to determine the optimum values of those parameters (Fig. 1 and Fig. 2). They were found to be $\alpha = 10°$ and $L = 1$ mm. As it is seen in Fig. 1, superluminescent emission power increases with the increase of tilted stripe angle. Besides, emission spectra halfwidth (FWHM) decreases with the increase of pump current, and this dependence the sharper the tilted stripe angle less. At the same time the spectral modulation depth $m = (P_{\max} - P_{\min})/(P_{\max} + P_{\min})$ increases, where $P_{\max}$, $P_{\min}$ are the maximum and the minimum peak intensities in the emission spectra. The value $m = 0.1$ was chosen as a threshold point of lasing regime (it is indicated on light-current curves in Fig. 1).

The sharp dependence of differential quantum efficiency of stimulated emission η_d on

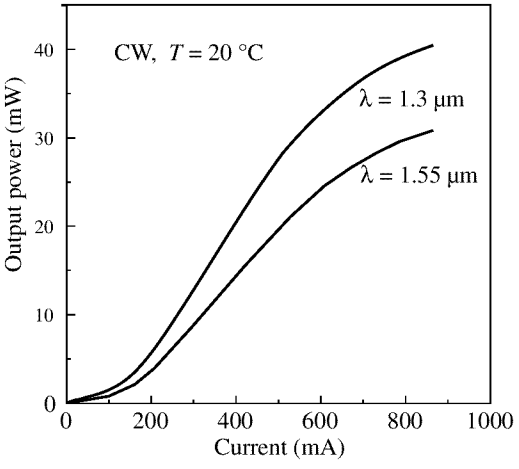

Fig. 3. Room temperature cw light-current characteristics of SC DH InGaAsP/InP (λ = 1.3–1.55 μm) SLDs with 10° tilted mesastripe (L = 1 mm) and back absorbing section (L = 300 μm).

SLD cavity length (Fig. 2) compared to laser diode one [11] is connected with single pass operation regime of SLD (η_d) decrease at short cavity length and an increase of internal optical losses (η_d decrease at long cavity length).

Maximum cw output power of superluminescent emission of tilted stripe InGaAsP/InP SLD (λ = 1.55 μm) measured at 0.1 spectra modulation depth reached 15 mW at optimum values α = 10° and L = 1 mm.

An introduction of additional back absorbing section in tilted mesa stripe SLD construction made it possible to widen the range of superluminescent emission. Such construction is similar to two-section laser diode construction described in detail in our previous work [10]. In SLD case the optimum lengths of pumped and absorbing sections were found to be 1000 μm and 300 μm, respectively. The cw light-currrent characteristics of two-section tilted stripe (α = 10°) InGaAsP/InP SLD are presented in Fig. 3. Such SLD construction allowed to receive 40 mW (λ = 1.3 μm) and 30 mW (λ = 1.55 μm) cw output power of superluminescent emission. Emission spectra FWHM is 60 nm (spectra modulation depth $m < 0.03$) and 65 nm ($m < 0.01$) at maximal output power $P_{\max}$ and operating output power $1/2P_{\max}$, respectively. The far field pattern is singlelobe with FWHM ($\theta_{\parallel}$ = 25° and $\theta_{\perp}$ = 40°), allowing efficient coupling into singlemode optical fiber.

Deposition of antireflection (AR) coating with reflection coefficient R = 1% on the front facet of SLD didn't result in perceptible increase of output power of superluminescent emission.

Further optimization of superluminescent diode efficiency is seen in the decrease of heterostructure internal optical losses and deposition of AR coating with R less than 0.1%.

Summary

We have demonstrated high power low coherence singlelobe InGaAsP/InP (λ = 1.3 – 1.55 μm) superluminescent diode. SLD uses two-section mesa construction with 10° tilted stripe of 4 μm width and 1000 μm length and back absorbing region of 300 μm length. CW output powers as high as 40 mW (λ = 1.3 μm) and 30 mW (λ = 1.55 μm)

were achieved. Emission spectra halfwidth is 65 nm with spectral modulation of less than 0.01. Singlelobe far-field pattern allows efficient coupling into singlemode optical fiber.

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